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Preface

Special Issue – Synthetic Biology

Already 100 years ago the concept of synthetic biology emerged when Stéphane Leduc [6] and Jacques Loeb [7] speculated over possibilities to create artificial living systems. Since then the idea of synthetic biology has evolved mainly as an approach of analysing, understanding, and improving biological processes for the production of desirable goods and functions. The introduction of recombinant DNA technology in the early 1970s added completely new options to such approaches. Since about 10 years the original concept of synthetic biology returned with a new orientation and an extraordinary dynamics [1–5]. Main drivers for this revival were the results of whole genome sequencing, which provided abundant information about the building blocks of living systems, and the concept of systems biology, which offered a new way for the understanding of how biological components function and interact in reality trying to explain structures and functions of biological systems.

There is no generally accepted understanding and delineation of synthetic biology. Many different definitions are discussed among scientific communities and it may be argued whether it would be relevant at all to have available a clear definition of the field considering its early stage and dynamics and accordingly many possible different routes of its future development. Nevertheless, what seems to make synthetic biology different from other current lines of biological research is the rigorous application of engineering principles (standardization, abstraction and decoupling) to biological research, which indeed offers a new way of doing research in life sciences.

In this special issue an overview of current advances in synthetic biology is given. We do not claim to cover the field completely. However, some of the most important tracks of research will be reviewed by a group of highly renowned researcher from different European countries thereby providing a unique compilation of the actual status and future perspectives of synthetic biology.

Kitney and Freemont will start the special issue with an overview of synthetic biology and its evolution during recent years addressing key issues in relation to the state of play. The following contributions are divided into two groups. A first group of papers is concerned with recent progress in conceptual and methodological approaches to synthetic biology. A second set of papers discusses how synthetic biology could contribute to important application areas such as health care, industrial biotechnology and environmental issues.

Rodrigo et al. elaborate on the perspectives of automatic design of regulatory systems based on computational modeling. The challenge is to find sequences of nucleotides that better fit a targeted behavior. Kepes et al. analyze the constraints that shape natural genomes and draw lessons for full genome design trying to explain the mismatch between our capability to synthesize DNA at genome scale and our low ability to design functional genomes.

Important facets of the application of engineering principles to living systems are abstraction and decoupling. The creation of orthogonal systems that work independently from the host system is one way into this direction. Herdewijn and Marlière explore novel biochemical systems made up of natural and xenobiotic nucleic acids (XNA). Neumann's paper is concerned with the expansion of the genetic code thereby designing organisms using entirely different genetic codes for translating information of the genome. Recent advances of orthogonal biosystems based on such approaches are discussed. Another line of research in this context is the ribosome independent biosynthesis introduced by Giessen and Marahiel.

Switches are important bioparts for synthetic biology. Wittmann and Suess explain how riboswitches can be used as intracellular biosensors which respond to any ligand and regulate gene expression. Hoener and Weber discuss the use of molecular switches in animal cells for regulation of important cellular processes and the application of such approaches for medical purposes. Putyrsky and Schulz describe a novel way of using the immunosuppressant rapamycic. It can be deployed as a photoinducible tool for activating cellular enzyme activity. Finally Jaeschke presents an overview of RNA photoswitches as new tools for controlling gene expression.

Most research in synthetic biology has been using bacterial systems. Two papers of this special issue are concerned with transferring the synthetic biology approach to higher organisms. Blount et al. provide an overview of research on regulatory networks in yeast, an important industrial production organism. Menolascina et al. discuss the use of synthetic biology in higher eukaryotic organisms and multicelllular organisms.

Cell chassis are the important vehicles for any synthetic biology construct. Danchin points out the significance of cell's chassis for the scaling up of synthetic biology. Chiarabelli et al. introduce another approach within synthetic biology – synthetic biology based on chemical manipulation. Malinova et al. take up the chemical perspective and discuss how synthetic chemistry could inspire synthetic biology.

A first series of papers dealing with applications of synthetic biology is concerned with health care. Firman et al. discuss the design of biosensor for detecting drug-target interaction at a single molecule level. Krams et al. analyze the application of synthetic biology to studying signaling pathways in endothelial cells covering an artherosclerotic plaque. Wohlleben et al. present an overview of new options for the engineering of novel pathways in actinomycetes for optimsing production of antibiotics based on synthetic biology. Nguyen et al. review the application of metabolomic methods for optimizing microbial secondary metabolism,

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which holds great potential for producing new compound with medical value.

Potentials of synthetic biology for industrial biotechnology are discussed by Lam et al. focusing on advances of synthetic biology with respect to bacterial biosynthesis for value added products. Schiel and Duerre review pathway engineering in acetogenic anaerobic bacteria for the production of bulk chemicals and biofuels using waste gases thus avoiding competition with nutritional feedstock.

Finally Schmidt and de Lorenzo discuss how safe and efficacious firewalls to curtail interaction between synthetic constructs and the environment could be constructed, which is an important prerequisite for any field environmental applications of synthetic biology.

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